Hydraulic drive and control system of the cone collecting robot[1]

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Abstract: This paper describes the basic structure and design and operation principle of the hydraulic drive and control system with two pumps and two circuits. The manipulator of the cone collecting robot designed is full driven by hydraulic, which has five freedoms. The computer and electrohydraulic proportion velocity regulating valve were installed to realize open loop serve control for reducing cost and easy application.

Keywords: Cone collecting Robot, Hydraulic system, Serve control

Basic structure of the robot

The basic structure of the robot includes three parts: picking manipulator, running part (crawler tractor), computer numerical control system.

The shape of the manipulator of the robot was shown in Fig. 1. The manipulator has two 6-m long arms. On the top of the forearm, there are two tooth-like picking combs, 0.5 m in width and 0.85 m in length, made of $60Si_2Mn$ steel and were driven by the hydraulic system. The combs can sway left and right, turn up and down, and can open and close like tooth.

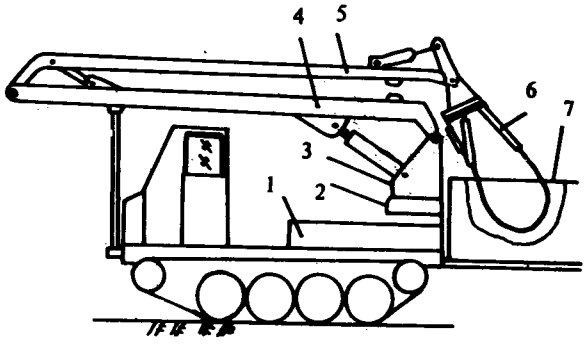

Fig. 1. General structure of the robot

1. Machine frame; 2. Rotary disk; 3. Vertical prism; 4. Upper arm; 5. Forearm; 6. Picking combs; 7. Collecting box of cone.

The moving part of the robot is a J-50 tractor, which is fit to travel in mountain terrain.

Computer numerical control system controls the electrohydraulic proportion velocity regulating valve and solenoid valve. The manipulator arms are operated by high-pressure gear dual pump. Integrative blocks of hydraulic system and computer control system are both located on the rotary disk that is joined with the tractor frame. Pump and oil tank are placed between the rotary disk and the driver's cab.

Principle of the hydraulic drive and control system

The manipulator of the Robot has five freedoms, full hydraulic driving, and adopts computer and electrohydraulic proportion velocity regulating valve to realize open loop serve control (see Fig. 2). Five freedoms of the manipulator are controlled by Revolving motor (25), upper arm cylinder (22), forearm cylinder (17), wrist joint cylinder (14) and shaking cylinder (8). Solenoid relief valves (1) and (4) regulate the pressure of high-presser gear dual pump (2) and (3) in working state and discharge pressure while it is not working. Electrohydraulic proportion velocity regulating valve (12) and (19) controls the cylinders moving speed. The power of solenoid valves (6), (10), (13), (15) and (24) are provide by a 24 volt-accumulator.

Cylinders (22) and (17) controlled by valve (19) and (12). Revolving motor (25) drive the rotary disk to revolve the manipulator by gear and worm-gearing transmission. The manipulator revolves without limitations in any directions. The wrist joint of the manipulator, driven by cylinder (14) and shaking cylinder (8), can sway towards left and right within swinging angle of 135° and turned up and down within the about 90°. The picking combs are opened and closed by Cylinder (11), with a maximum open of 0.9 m. Valve (18), the pressure-sensitive switch, controls the solenoid valve (20) off when the cylinder (22) is overload.

[1]This project was supported by National Advanced Tech. Research and Development Program (863 Project)
Received: 1999-06-08
Responsible editor: Chai Ruihai

Operation procedures of the manipulator

The operating procedures of the manipulator and solenoid valve are as follows:

1) Start: Switch on, starting dual pump;

2) Lift: Two Proportion valves (19) and (12) and Solenoid valve (20) and (15) control both upper and forearm lifting;

3) Rotating: Solenoid valve (24) controls Rotating motor (25) rotating left or right;

4) Booming up and down: Solenoid valve (13) controls wrist joint cylinder (14) and makes the combs booming up or down;

5) Swinging combs: Solenoid valve (6) controls Swinging cylinder 8 and makes the combs swinging left or right;

6) Opening combs: Solenoid valve (10) controls comb cylinder (11) and makes combs open;

7) Driving forward: Two Proportion valves (19) and (12) and Solenoid valve (20) and (15) control both upper and forearm and make the combs driving forward;

8) Closing combs: Solenoid valve (10) controls combs cylinder (11) and makes combs close;

9) Operating backward: Two Proportion valves (19) and (12) and Solenoid valves (20) and (15) control both upper and forearm and make the combs operating backward;

10) Rotating back: Solenoid valve (24) controls Rotating motor (25) moving left or right rotating back;

11) Descending back: Solenoid valve (20) and (15) control both upper and forearm descending back;

12) Turn off: Stop the dual pump and turn off all switches.

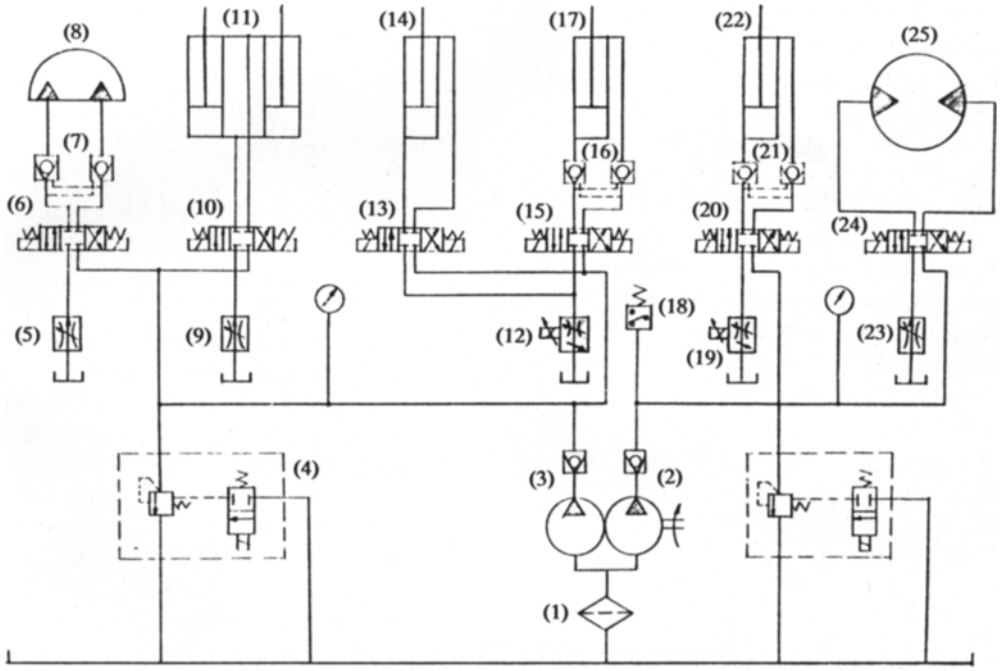

Fig. 2. The principle of hydraulic drive and control system

(1), (4)—solenoid relief valves; (2) and (3)—dual pump; (5), (9), (23)—restriction valve; (6), (10), (13), (15), (20) and (24) --solenoid valve; (7), (16), (21)—two pilot-operated check valves; (8)--swinging cylinder; (11)—picking combs operating and closing cylinder; (12) and (19)--electrohydraulic proportion velocity regulating valve; (14)-- wrist joint cylinder; (17)--forearm cylinder; (18)—pressure-sensitive switch; (22)—upper arm cylinder; (25)—rotating motor.

Computer numerical control system

The computer numerical control system of open loop control is used in the robot since the cone collecting operation is not required very high accuracy. The control system includes 14 switch parameters and 2 imitation parameters. This is a valve controlling cylinder's system, which regulates input electricity current to change open area of eletrohydraulic proportion velocity regulating valve.

The open area is calculated as follows:

$$A=kX \tag{1}$$

Where A is open area of the valve; k is constructive parameter; X is distance.

$$X=FI \quad (2)$$

Where F is solenoid function parameter; I is electricity current.

Flow quantity input to cylinder regulating by open area of the proportion valve.

$$Q = CA\sqrt{2\Delta p / \rho} \quad (3)$$

Where Q is flow quantities input to cylinder; C is low quantity parameter of the valve; Δp is pressure difference of the valve, ρ: flowed liquid density

Cylinder moving velocity is equal to moving velocity of picking combs. It is decided by the following flow quantity equation.

$$V=Q/A \quad (4)$$

Where V is cylinder moving velocity.

We can control position of picking combs by moving time.

$$H=V t \quad (5)$$

Where H: position of picking combs; t is moving time of picking combs.

The manipulator can be continuously operated. Its operative procedures are: opening the picking combs (0.9 m maximum, variable); grabbing forward (traveling 2 m, variable); making the picking combs closed; operating backward (traveling 2 m, variable); descending the manipulator (traveling 1 m, variable).

The considerations for control the operation of the robot are as follows:

1) To press initiate button to make the forearm move and also the upper arm move 2 or 3 seconds later;
2) The plucking combs are opened and turned to the tree-branches when reaching enough height at the working place;
3) The claws go forward, closing at the enough depth, and collecting cones;
4) The claws go back, and then open; the cones fall down to the box located at the rear of frame;
5) The claws revolve to the other objects, repeating the procedures above;
6) All operations can be quickly and accurately completed with no damage to the trees;
7) If fault, the robot will be automatically stopped and checked;

The cone collecting robot was put in to use in Daxianan Mountain Forest Areas, Northeast China. It was shown that the robot could be easily operated safely and efficiently, moved flexibly, and fitted to cone collecting very much.

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